CHAPTER 24: BUYING A BOILER

When buying a boiler we must take into account:

1- The fuel (or fuels and their quality under the worst conditions).

Not all types of boilers can burn every type of fuel.
We can establish that if the boilers are specifically designed for their respective fuels, the following approximate ratios apply:

1 Lt of heavy fuel oil is equivalent to 3.0-3.5 kg of firewood with 25% moisture content.

1 Lt of heavy fuel oil is equivalent to 1.05-1.15 m³ of **natural gas** (Paysandú Uruguay natural gas).

1 Lt of heavy fuel oil is equivalent to 3.3-3.6 kg of **rice husks** with 10% moisture content.

These values are affected if the boilers have heat recovery systems, which is not always possible (due to corrosion problems).

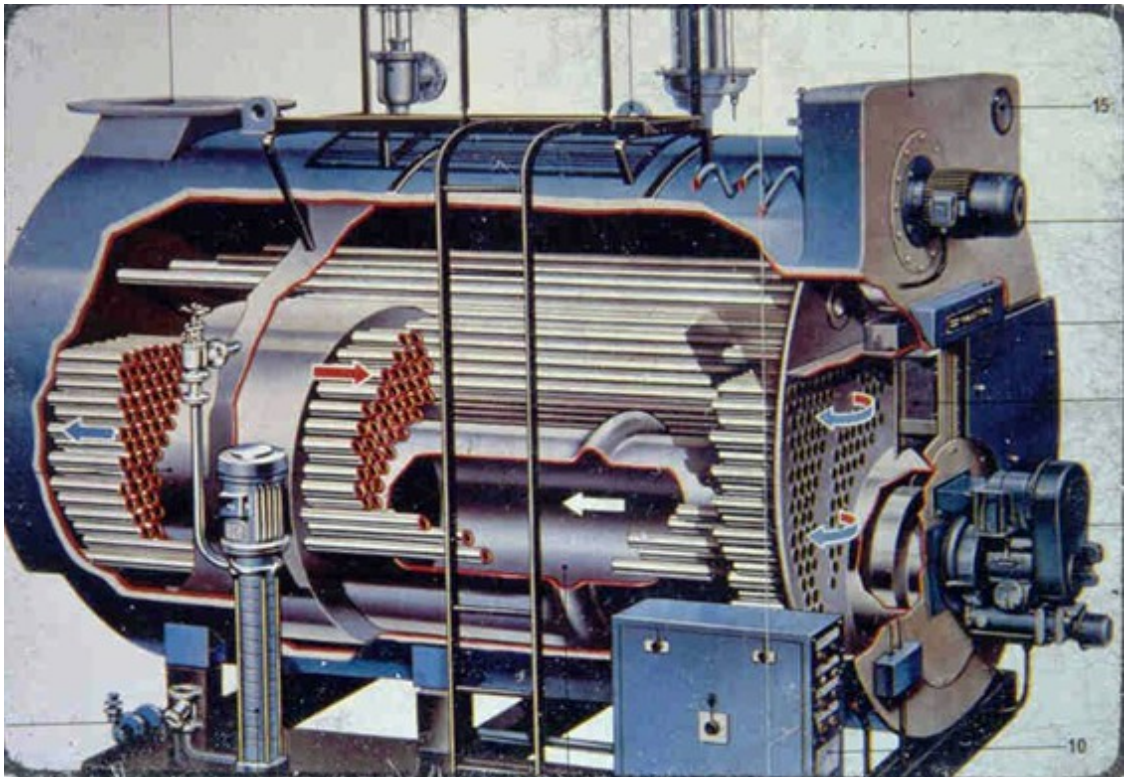
When a boiler is intended to burn natural gas, it's essential to consider whether the design is suitable for natural gas combustion. Otherwise, there's a risk of loosening tubes and cracks in the hottest plate, since gas has a higher temperature at the end of the combustion chamber due to its different heat transfer compared to liquid fuels.

The latter have a more radiant flame, located closer to the burner, which cools the flame rapidly in the combustion chamber before it reaches the hottest plate.

Furthermore, when burning natural gas, a fuel that is very difficult to store and subject to supply interruptions, it's advisable to have alternative fuels available (such as a dual-fuel burner that can burn either liquid fuel or natural gas).

2- The quality of the makeup water and condensate, and the possibility of treatment (chemical and mechanical cleaning).

Some boilers cannot tolerate process contaminants (oils, grease, etc.), others cannot tolerate sludge or are sensitive to any kind of scale buildup, and still others are prone to accumulating contaminants, etc. Not all types, and even within those types, not all models have mechanical access for cleaning.



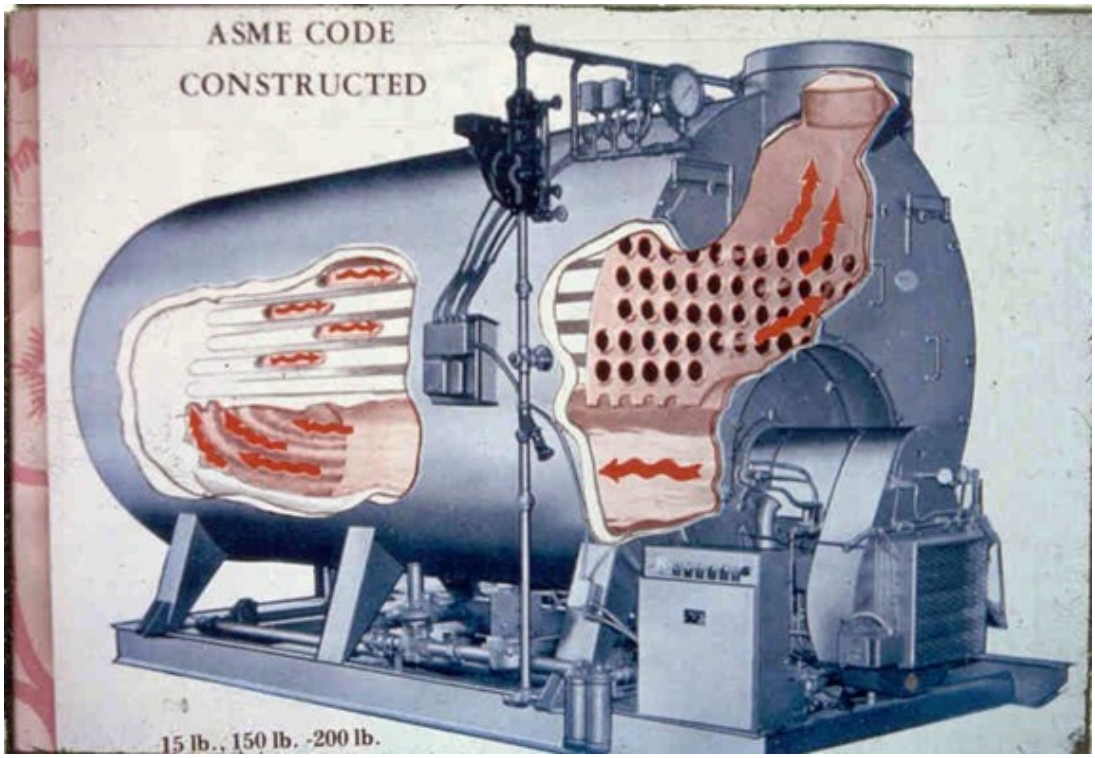
3- Normal operating pressure and its limitations (response).

Some boilers are slow to respond to pressure changes, which affects their performance or steam quality.

4- Temperature (saturated or superheated steam) and steam quality ("quality," "title," or moisture and purity).

Depending on its use, the temperature and quality of the steam are key.

A boiler may not function correctly for supplying steam to a turbine (due to entrainment and the need for superheating), or the desired steam purity may affect the process (dyeing, food processing, etc.).



5- Hourly Steam Capacity (kg/hour) and Overload Potential (%).

This capacity must be calculated based on the plant's maximum steam requirements, considering a "peak" or overload percentage for plant startup or for anticipated future increases in steam consumption.

When expressing boiler capacity, care must be taken, as it varies according to steam pressure and feedwater temperature.

One way to avoid this confusion is to express the **steam capacity in kg/hour of steam at 100°C / 212°F** (evaporation equivalent), or alternatively, to express the parameters mentioned above: pressure, steam temperature, steam quality, and feedwater temperature (both expressions are interchangeable).

We must consider that the appropriate capacity at which the boiler will be used should not only be the point of maximum efficiency, but also ensure adequate steam quality.

Generally, around 70% is ideal, since when the boiler operates above 70%, steam quality problems arise: carryover and foaming, related to established chemical limits. This is because specific vaporization is currently very high, which means a greater degree of internal instability.

The hourly steam capacity in kg can also be established in relation to the hourly fuel consumption. Therefore, we can establish the following approximate relationships for a saturated steam boiler with a pressure between 7 and 10 kg/cm²:

1 Lt of heavy fuel oil.....12.5 to 14.5 kg of steam

1 kg of 25Hbh firewood.....3.8 to 4.8 kg of steam

1 kg of 10%Hbh rice husks.....3.6 to 4.2 kg of steam

1 m³ of natural gas (Pay) .....12.5 to 13.5 kg of steam

These values are related to the boiler design, operating percentage, heat recovery units in the flue, excess air, combustion quality, feedwater temperature, saturated steam, superheated steam, insulation, losses and blowdown, etc.

6- Overall Efficiency relative to the LHV (%) at 100% capacity.

This allows us to get an idea of the kg of steam per kg of fuel to compare different offers. (The fuels and other parameters must be the same for the comparison to be valid).

Here, the overall efficiency of the boiler will be indicated (Combustion and Transfer Efficiency, Boiler Efficiency as a thermal equipment: insulation only, since it is assumed that the blowdown valves will be closed during the test and there should be no water or steam leaks).

This Overall Efficiency relative to the LHV at 100% capacity is currently around 90% at the LHV. (since the Thermal Efficiency in general is between 97% and 99%, and the Combustion and Transfer Efficiency is between 88% and 91% at the LHV, both depending on the type of boiler related to the type of fuel and its heat recovery systems.

Remember that 100% capacity is not the point of maximum efficiency (it is generally close to 70%).

It's important to note that when we refer to Efficiency based on the Lower Heat Load (LHV), the percentage provided is more representative of the boiler's performance, while Efficiency based on the Lower Heat Load (LHV) provides a percentage that better reflects the fuel's behavior.

Americans (USA) generally use LHV Efficiency, while in Europe (and typically in Uruguay), LHV Efficiency is used.

The key point here is to be very careful when comparing offers (economic proposals for buying or selling new or used boilers) with efficiencies expressed in different units.

Generally, LHV Efficiency is a few percentage points lower than LHV Efficiency, and the greater the difference between the fuel and LHV, the lower the percentage difference. and the PCI, this difference will be greater, although although the % in numbers are different, they indicate the same thing, since each % of Efficiency expression must be multiplied by the respective PCI and both will give the same amount of heat used.

7-Combustion Efficiency (LHV) over time.

Cleaning periods without a noticeable loss of efficiency are generally observed as an increase in flue gas temperature, thus increasing the heat loss.

This allows for advance planning of downtime for cleaning (which has a cost) and whether fuel consumption will increase excessively between periods due to efficiency loss from boiler fouling.

The flue temperature is most affected by fouling of the heat transfer surfaces, and therefore combustion and heat transfer efficiency decreases between cleaning periods.

8-Safety System:

Safety valves (2 minimum recommended), level controls (2 minimum with combustion cutoff), level control valves, pressure switches, alarms, fusible plug (if required by regulations), etc.

Verify that the safety valves are indeed fully open, have differential pressure, and include a test lever.

9-Purge Blowdown System:

-Level purges blowdowns (connected for full opening),
-Bottom blowdowns (preferably a double valve with a quick-acting one),
-Continuous (surface) blowdown.

10-Inspection and Cleaning Access Points:

Manhole if necessary, head and hand access (near the blowdowns, feed inlets, bottom sections, and top section for monitoring chemical and mechanical cleaning).

11- Feed pump with sufficient capacity for extended service (pressure and capacity), taking into account the water's chemical conditions and temperature (packing or mechanical seal), intermittent or continuous service (continuous regulation), efficiency (or power consumption).

Alternative feed system: steam injectors or alternative pumps (cellulosic combustion boilers: wood, husks, etc.)

12- Combustion control: systems related to its safety, continuous modulation (best efficiency is achieved), semi-modulated (by steps), or intermittent (on-off) with the lowest efficiency.

13- Construction and testing standards: ASME, NBN, VDTUV, IRAM, CECT, etc.

14- Warranty, inspections during and at the end of the warranty period.

With direct and indirect efficiency measurements.

Within the manufacturing controls: it is important to ensure compliance with construction inspections, especially radiographs of welds in areas specified by the standards (envelopes and domes, etc.), stress relief according to standards, which is done by annealing (normalizing) of pressure-bearing parts (generally enclosed with their plates, furnaces and domes, etc.), the specified hydraulic tests, etc.

Before buying a boiler, it is advisable to: ask the manufacturer for locations where similar equipment is installed, visit these establishments in person, and speak not only with the managers but also with the boiler operators in charge of the boilers (without the boiler manufacturer present, as a follow-up visit can be arranged later, during which you will be prepared to ask questions).

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On the first visit to the supplier of the new (or used) boiler, it is advisable to ask about:

Compliance with the boiler specification and NAMEPLATE.
Response to changes in consumption.
Warm-up time for commissioning.
Periods between cleanings and
flue gas temperature variations during those periods.
Problems with steam quality.
Loosening of tubes.
Furnace explosions.
Response to different fuel qualities.
Ease of cleaning the flue and water sections.
Steam output (kg of steam per kg of fuel,
if wood, ask about moisture content).
Number of personnel required for operation.
Limits on fuel quality (moisture content for wood).
Limits on feedwater quality (entrainment problems or foaming).
Areas of poor water circulation (likely sludge deposits).
Heat recovery systems (efficiency and cleanliness).
Ease of operation, etc.

One of the most important limitations in boiler combustion is the maximum amount of heat per cubic meter (kcal/m³) that can be released in the combustion chamber (average in kcal/m³), as well as the maximum peak heat flow per surface area (kcal/m²).

It is crucial to ensure that the manufacturer complies with this standard, as it is closely linked to the safety of cylindrical combustion chambers, in particular.

For example, in fire-tube boilers, the limit is 1,250,000 kcal/m³ according to the British Engine Regulations, and the peak heat flow limit per surface area of the combustion chamber is 250,000 kcal/m² according to ABG 28, etc.

This limit affects even the thickness of the cylindrical combustion chamber material. In water-tube boilers, this limit affects the water circulation within the tubes, which can potentially overheat and burn due to insufficient cooling.

The cylindrical combustion chamber of fire-tube boilers can be "corrugated" (with cylindrical shapes of varying dimensions and profiles, which allows the chamber to better withstand pressure and partially absorb the significant

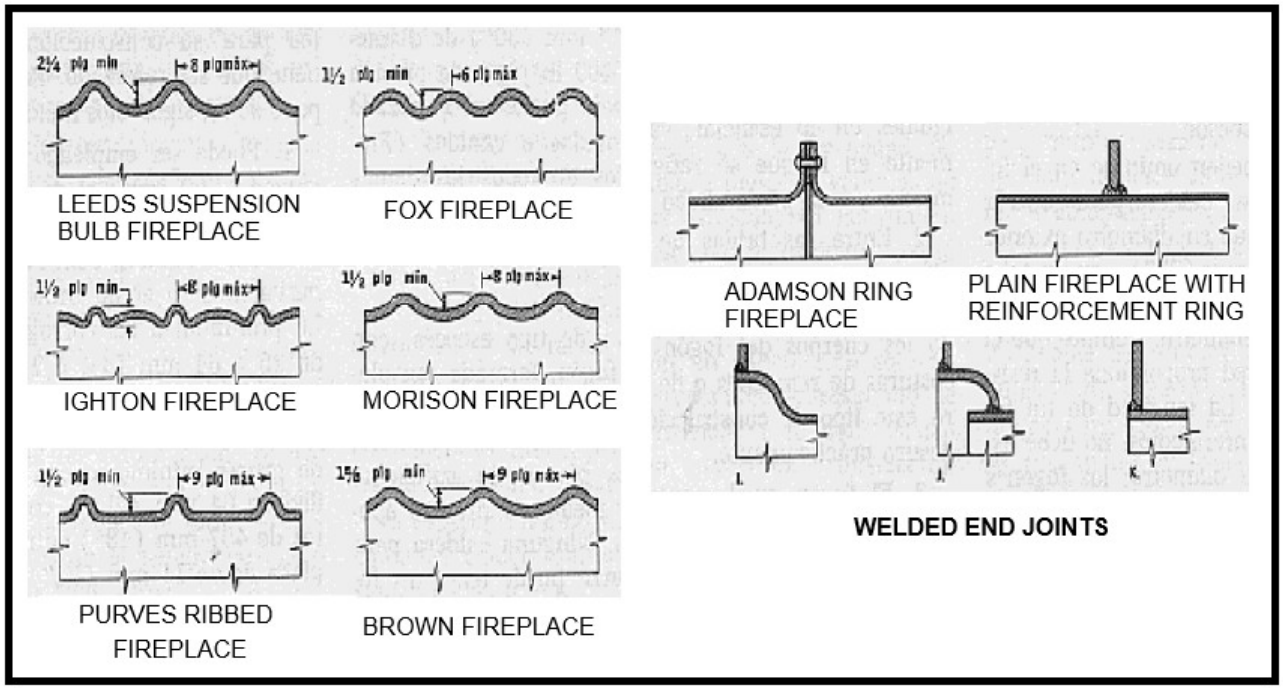
expansion stress caused by the high temperature of the flame inside).

Or "smooth" (a simple cylinder, which may have cylindrical supports, such as rings, on the water side, i.e., the cooled side; smooth cylindrical combustion chambers are limited to small-capacity boilers, since the problem of expansion is not taken into account, although in some cases a single "ruffle" or "expansion joint" is added for this purpose).

The most common "corrugated" system is the FOX system (since it is the simplest to manufacture).

Typically, once the firebox has been rolled with a single longitudinal weld, being rolled from a single sheet, it is placed on a type of lathe with embossing wheels shaped to create the "crisp" and torches that heat the material in the area to be deformed.

Another way to make a "corrugated" firebox is to create it in two halves using a press, after preheating the material to be deformed, and then welding the two halves together.



Different types of cylindrical smoke-tubular fireplaces

The expansion of the cylindrical combustion chamber in a fire-tube boiler causes stress between the plates (unless the combustion chamber is "floating," as in some return-flame boilers).

The tubes connecting the plates and the casing bear this stress, since the heating of the combustion chamber at certain times causes greater expansion than the tube passages.

Therefore, there are reinforced tubes, "stays," whose function is to withstand this significant stress and the pressure exerted by the boiler itself, which acts on the plates.

These plates are flat, and therefore their shape is not ideally suited to withstand stress that could distort them.

Today, tubes are mandrel-grooved and welded. Previously, in the 1900s, they were only mandrel-grooved and upset (that is, their ends were flattened or flared for two reasons: to better withstand stress and to prevent the protruding ends of the tubes from burning during the first pass, where the temperature reaches 900°C at the furnace outlet).

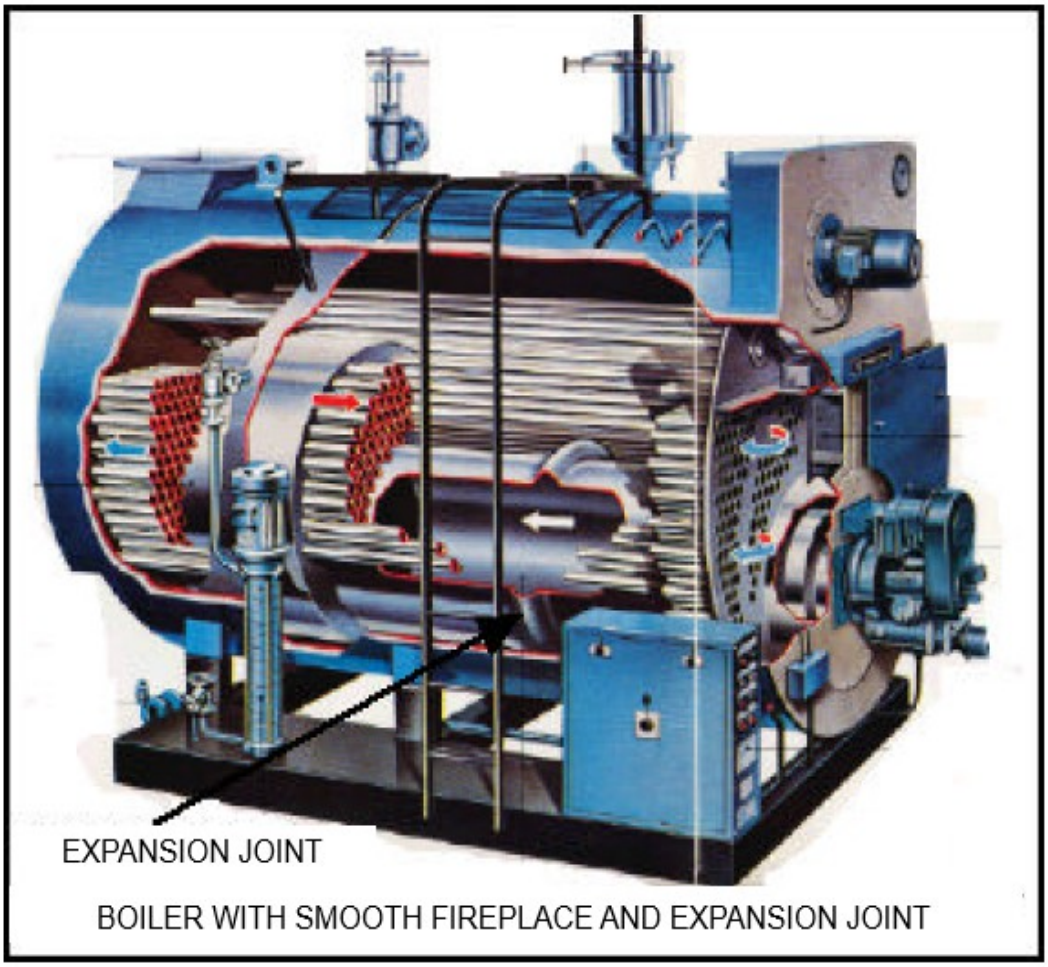
Stay tubes used to be thicker, sometimes with securing nuts. Today, these tubes are generally welded with a stronger weld, a deeper weld, than tubes that only need to maintain a watertight seal through welding.

When a boiler is scaled, the combustion chambers, plates, and tubes experience less cooling, leading to increased expansion that tends to crack the mandrel welds, loosen the mandrel tubes, crack the tubes and plates between tube holes, or even cause cracking at the combustion chamber ends, or, in some cases, fatigue and collapse.

This same problem of abnormal expansion occurs when boilers are heated too quickly from a cold state.

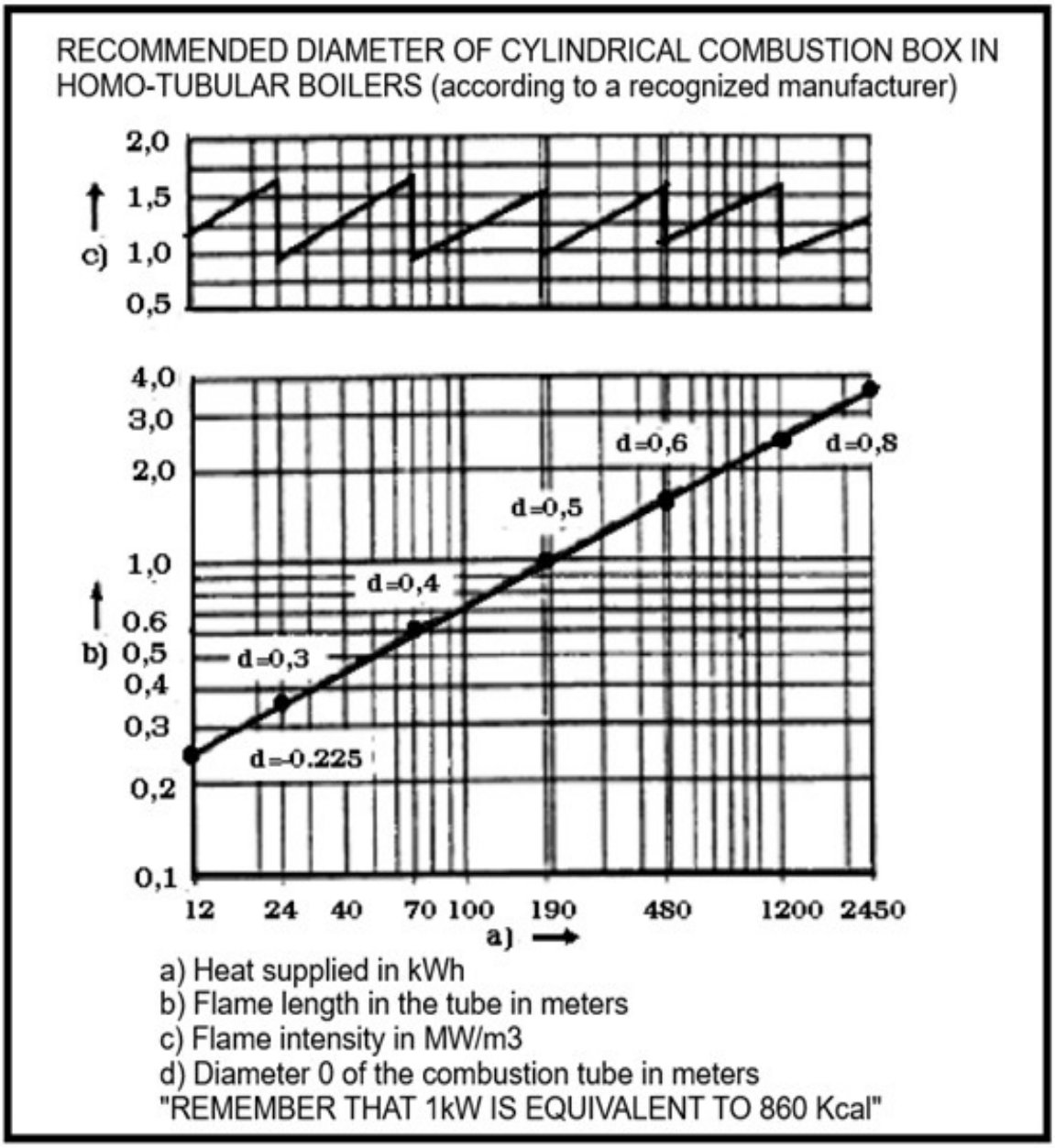
The same thing happens when the chemical conditions of the water do not allow for proper cooling of the transfer surfaces, due to alteration of the internal circulation (high TSD, high pH, alkalinity, etc., or contamination with elements that alter the surface activity of the water.

All these problems are observed when there is "agitation at visual levels" above normal, and the solution is generally to open the "continuous purge blowdown" to the maximum until this situation passes; it is also advisable to lower the boiler's vaporization until this moment of agitation passes).



BOILER WITH SMOOTH FIREPLACE AND EXPANSION JOINT

But whatever the type of cylindrical hearth, there is a **minimum diameter for each maximum combustion power of the boiler.**



The diameter of the combustion chamber in a fire-tube boiler plays a very important role, especially in the combustion of fuel oil, since the flame needs sufficient space within the diameter so that the atomized fuel does not "collide" with the relatively cold wall of the cylindrical combustion chamber and prevent its proper combustion.

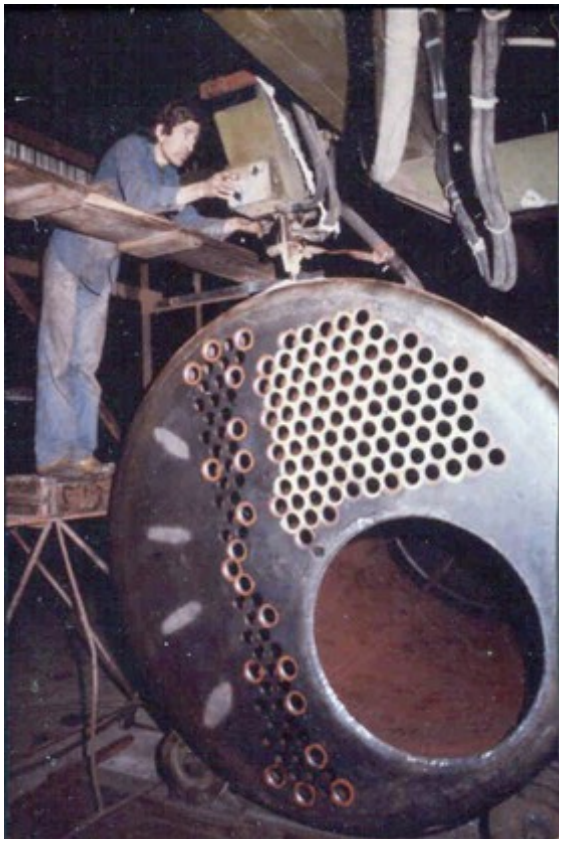
This situation is not corrected by the atomization angle, since for a certain combustion "power", this diameter must have a minimum.

Other ways to express boiler steam output: We can say that a boiler's steam output is 40 kg/h of steam per m² of heating surface.

This means the boiler's steam capacity in kg is given by the expression: kg/h/m² x heating surface = kg of steam per hour

We must specify the pressure, steam and water temperatures to be used, or the equivalent kg of steam at 100°C (212°F).

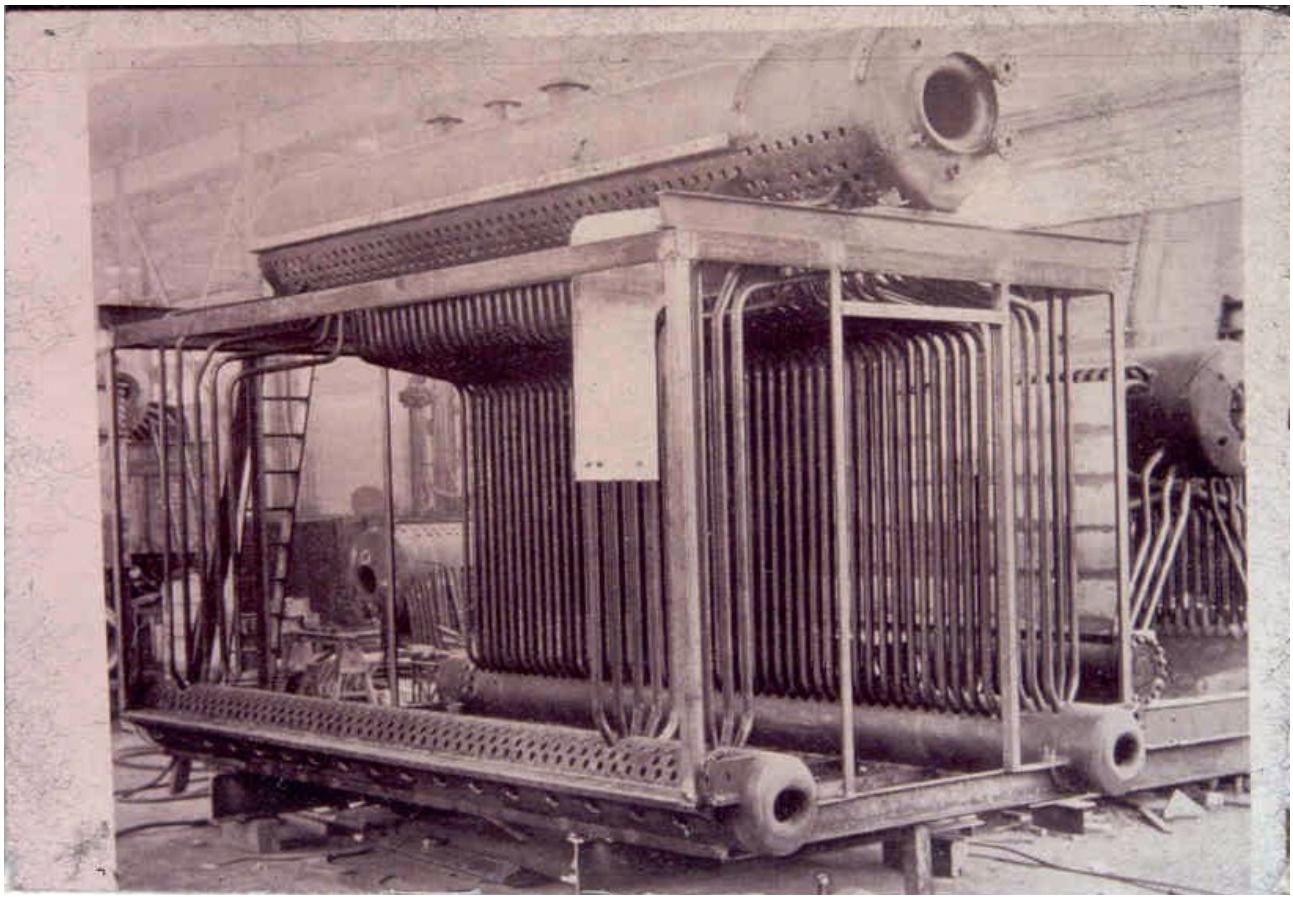
In older boilers, this value was around 15-20 kg/h/m², while currently it is more than 50-55 kg/h/m² in fire-tube boilers.



The United States (USA) expresses steaming capacity in "boiler horsepower" (BHP): 1 "horsepower" is equivalent to 33,475 BTU/hour or 8,502 kcal/hour (approximately 30 lbs. of steam at 70 PSI gauge with feedwater at 100°F (37.7°C)).

That is, approximately 13.6 kg of steam at a pressure of 4.9 kg/cm² (69.7 PSI gauge with feedwater at 37.7°C (100°F).

This average expression in kg/m², which refers to the total heating surface, should not be confused with the maximum permissible limits for households, which also refer to surface areas.

Currently, it is very common to express boiler capacity in kWh (kilowatt-hours, 1 kWh = 860 kcal), both combustion capacity and steam production capacity.

Joules, or better yet MJ (megajoules), are also used. Remember that a mega is 1,000,000 times a second, and that a joule is equivalent to a watt, a unit of measurement per second. Converting this to kWh, 3.6 MJ is equivalent to 3.6 MJ, since one kWh is equal to 860 kcal, or 1 MJ = 860/3.6 = 238.9 kcal.